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Contributed paper

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A cryogenic plant will be installed at the National Synchrotron Light Source II (NSLS-II) to supply the liquid helium for six superconducting cavities. This paper describes the configuration of the cryogenic plant and the main design considerations for selecting equipment and components.

1. Introduction

National Synchrotron Light Source II (NSLS-II) is a new 3 GeV, 500 mA light source facilty under construction at Brookhaven National Laboratory (BNL) Its 792-m storage ring (SR) will contain four 500 MHz superconducting Radio Frequency (RF) cavities and two 1500 MHz superconducting harmonic resonators (HRs), installed in two separate sections (see section layout, figure 1). An independent cryogenic plant will supply liquid helium (LHe) and liquid nitrogen (LN2) to the RF sections.

2. Cryogenic system components

The cryoplant will consist of the following major components: (i) turbine-based cold box, (ii) LHe Dewar, (iii) two main compressors and a recovery compressor, (iv) oil removal and dryer systems, (v) a manifold, (vi) valve boxes, (vii) ambient vaporizer, (viii) transfer lines and (ix) gaseous He storage tanks; see figure 2.

The turbine-based *Cold Box* and *Dewar* together represent the refrigeration/liquefaction unit. This unit is placed as close to the RF sections as possible to minimize heat losses and costs. Each of the two *main compressors* will be capable of handling the full load of the system with the other compressor serving as a backup. A smaller *recovery compressor* on emergency power will be able to handle all boiled-off helium from the static heat loads of 400 W in the case of a power failure (table 1). The oil removal and dryer systems will ensure He gas purity of 99.995 % or better.

From Dewar the LHe distribution will be split into three branches by the *manifold*: two for RF sections in the storage ring and one for testing room in the RF building. Each of the two *valve boxes* will supply LHe for two 500 MHz RF cavities and one 1500 MHz HR cavity. Additionally, the valve box will switch and redirect the warm He gas return to the cold return at the temperature threshold of about 50 K.

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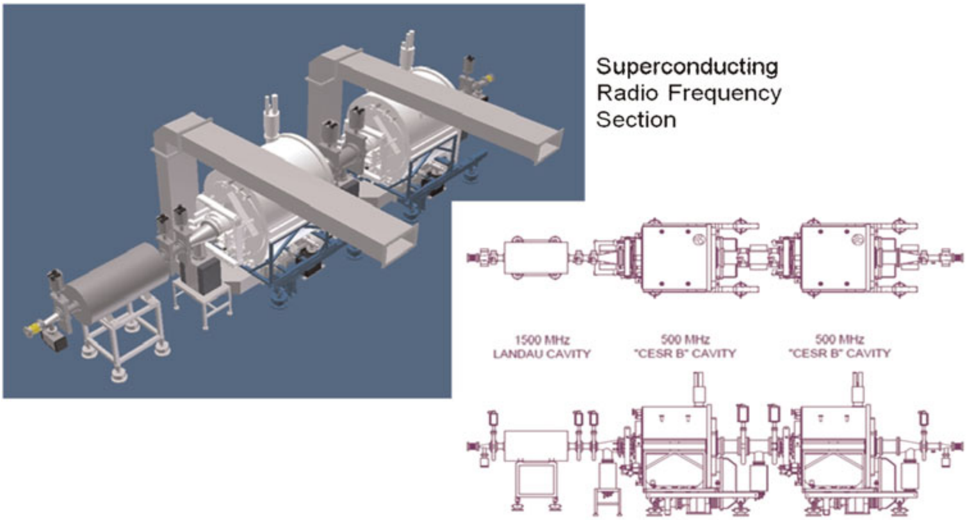

FIGURE 1. RF section layout.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Dates	2012	2014	2017	2019	2019
Voltage (MeV)	2.4	3.3	5	5	6
500 MHz RF cavities (Qty.)	1	2	3	4	4
Q cavities ($\times 10^9$)	0.75	0.75	0.75	0.75	0.5
1500 MHz HR (Qty.)	1	1	2	2	2
Q resonators ($\times 10^9$)	0.15	0.15	0.15	0.15	0.15
Valve boxes (Qty.)	1	1	2	2	2
500 MHz RF cavity static heat load (W)	43.04	86.08	129.12	172.17	172.17
1500 MHz HR static heat load (W)	37.20	37.20	74.40	74.40	74.40
Total static load (W)	80.2	123.3	203.5	246.6	246.6
Contingency: RF cavity and HR (%)	10	10	10	10	10
Total static load plus contingency (W)	88.3	135.6	223.9	271.2	271.2
500 MHz cavity dynamic heat load (W)	98.3	73.8	113.4	76.5	175.3
1500 MHz HR dynamic heat load (W)	19.8	37.5	43.1	43.1	110.1
Increments in dynamic heat load (W)	118.2	111.3	156.5	119.5	285.4
Total dynamic and static load (W)	198.4	234.6	360.0	366.1	532.0
Contingency: dynamic load increase (%)	50	50	50	50	30
Total dynamic and static loads plus contingency (W)	265	303	459	450	642
Total: valve box, manifold, transfer lines, Dewar (max. anticipating value) (W)	35	50	70	100	100
Total (anticipating value) (W)	300	353	529	550	742

TABLE 1. Heat loads

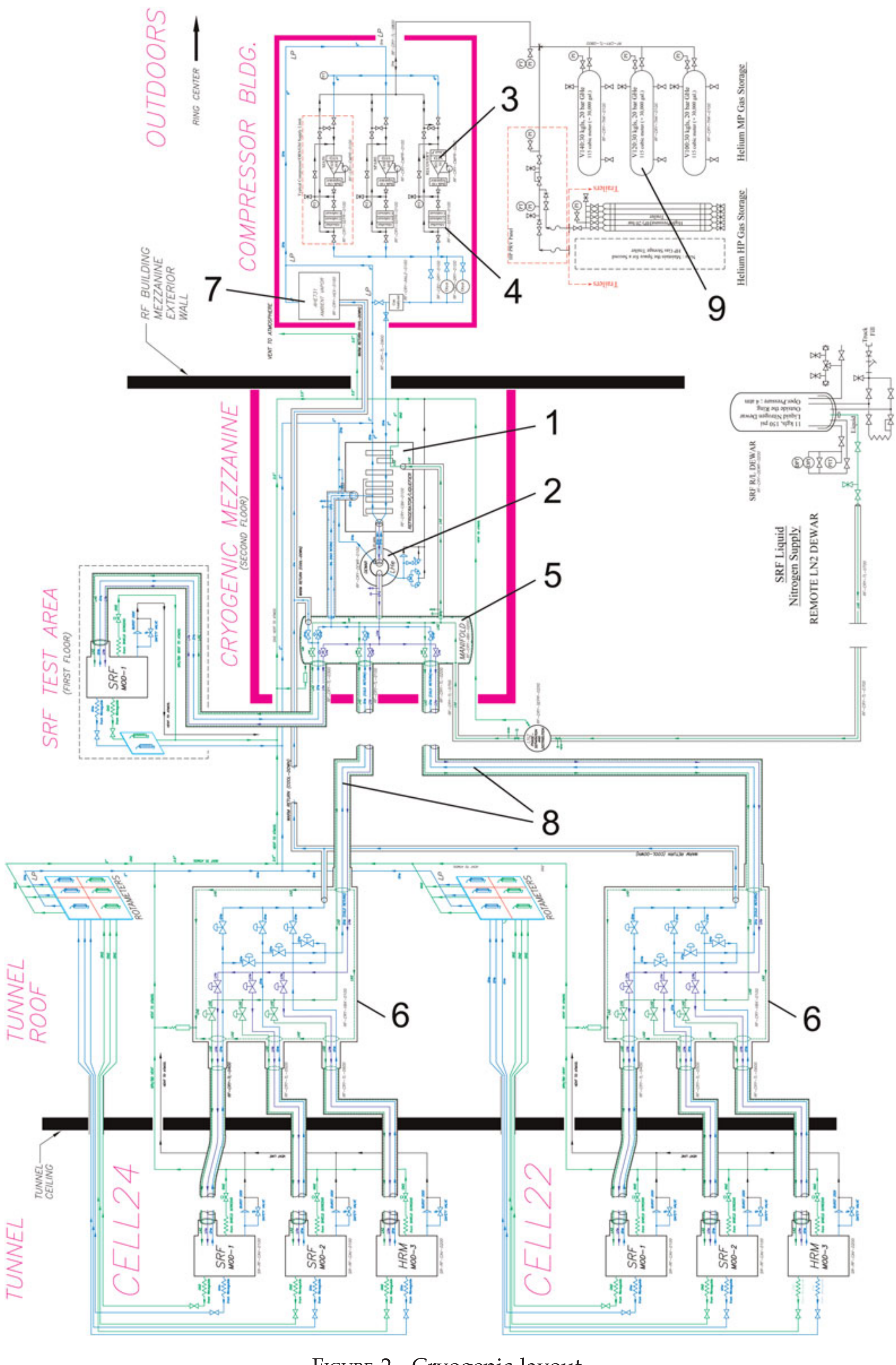

FIGURE 2. Cryogenic layout.

The nitrogen-shielded multichannel *transfer lines* with insulated jackets will be specified to have a heat leak less than 0.05 W m^{-1}. The transfer line size will be chosen to limit the total pressure drop to 120 mbar maximum from cryostat to the suction point of the compressor. This will allow for an available pressure drop of ~50 mbar for the regulator valve WEKA AG in the valve box to insure its stable operation.

The *ambient vaporizer* will be required to bring the temperature of the 'warm' (above ~50 K) He gas return up to ambient temperature for normal operation of the compressors. The required performance is to warm about 21–22 g s^{-1} of He gas resulting from 400 W of static load. To provide ample provision for storage of boiled-off from the system, three *gaseous He storage tanks* certified for operating pressure of 2 MPa (20.0 bar) and a total volume of 345 m^3 (~90 000 gallons) will be installed.

3. Heat loads

The estimated heat load for the fully built-up configuration is 816 W. In the case of a power failure the system is designed to handle a static heat load of 400 W. Both numbers includes 10 % increase that performance degradation over time.

Initial commissioning will be done with one RF cavity and one resonator.

4. System pressures

The cryoplant is designed for a nominal cavity operating pressure of (1.220 ± 0.0015) bar. The maximum operating pressure is 1.250 bar with the relief valve and burst disk pressures set at 1.350 and 1.410 bar, respectively. A maximum allowable working pressure of 1.490 bar is used for the cryostat design and its pressure vessel safety evaluation. The relief valve and the burst disk are properly sized to release the intense He boil-off in the case of a catastrophic vacuum failure (e.g. broken bellow).

5. LHe supply requirements

The cryogenic system will be able to operate continuously at output capacity levels ranging from 0 to 100 %, at either the maximum *refrigeration* or *liquefaction*. Additionally, LN2 will be used for pre-cooling to increase performance. The maximum cooling requirement for the cryogenic system will be to supply LHe for a period of 6 h at a rate of 300 l h^{-1} for cooling down a test RF cavity while supplying enough *refrigeration* to cover 400 W of the static heat load for the six other cavities concurrently. The cool down rate will limit the transition time from 130 and 70 K to about 1 h to minimize performance degradation due to any dissolved hydrogen in niobium.

6. Control system

The main control system at the operator level is EPICS and all EPICS input/output (I/O) controllers will use Moxa NPort 6650, running under the Linux operating system. All programmable logic controllers can be either Allen-Bradley (CompactLogix or above) or Siemens (S7-300 or above), and designed to interface with the NSLS-II control system. Networked instrumentation will be isolated over a separate network with independent switches. A restart of all I/O controllers would not interrupt the operation of the system.

7. Present status

The construction of the cryoplant building has commenced on site and the erection of metal construction, foundation and roof will be completed in July 2010. We expect to have a procurement package sent out for bidding by the end of August 2010. The cryoplant is scheduled to be delivered and commissioned in 2012.

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